Report on the Calibration of a Photoelectric

Standard for Harvard College Observatory*

by

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Summary

The photoelectric yield of a 2.6 x 1.3 cm sample of tungsten (sample "B"), furnished by the Harvard College Observatory has been measured at the wavelengths 584 Å, 735 Å, 1048 Å and 1216 Å. The yield was determined by measuring the ratio of the number of photoelectrons ejecter per second to the number of photons per second striking the sample. The photon flux was measured with a calibrated thermopile at each wavelength and checked against a rare gas ionization chamber at 584 Å and 735 Å. Corrections were made to the thermopile results to account for intensity distributions, the variation in sensitivity along the surface of the thermopile and the effective loss of sensitivity (2-6%) due to photoelectrons being ejected from the thermopile (the latter having been measured for another thermopile of the same construction[1]).

Apparatus

Radiation of wavelengths 584 Å, 735 Å, 1048 Å and 1216 Å was obtained from a 1m normal incidence monochromator, with a dc cold cathode discharge as light source. The apparatus for absolute yield measurements was part of a separate vacuum system attached to the exit arm of the monochromator (Fig. 1).

The measurement chamber contained the ionization chamber, calibrated thermopile and tungsten sample arranged in such a way that without disturbing the ionization chamber, either the thermopile or tungsten sample could be brought into the beam. The beam entering this chamber was stopped by a mask with a rectangular opening about 0.8mm x 5.0mm. A kinematic mounting insured that repeated locations of the thermopile relative to the mask could be made accurately.

The thermopile (Reeder), utilizing four extended junctions, had a sensitive area 1mm x 8mm, a time constant of $\sim$ 0.04 sec, a sensitivity of 2 $\mu V/\mu W$ and an ENI $\sim 2 \times 10^{-9}$ watts. About 0.5mm separated the thermopile surface and the mask when the kinematic mounting was engaged. Thus the area of the thermopile actually used was little more than the area of the opening in the mask. Calibration of the thermopile was carried out in vacuum using an NBS total irradiance standard (carbon filament lamp) with a calibrated silica window on the vacuum chamber. (Previous work[1] has shown the validity of calibrating a thermopile in the visible and infrared and employing the sensitivity figure thus obtained in the vacuum ultraviolet with the above noted corrections.) The mask was attached to the thermopile housing by the kinematic mounting for the calibration so that only the identical reduced area used for vacuum ultraviolet measurements was calibrated. A map of the relative sensitivity over the surface of the thermopile was obtained by scanning the thermopile (with mask attached) behind a 40 μ slit. Scans were taken along the length and width of the mask opening.

All thermopile measurements, both calibration and absolute flux determinations, were made using 13 Hz chopped light (at the source), ac amplification and synchronous retification in order to avoid the severe problems arising from thermal drift in the monochromator.

The ionization chamber, described in detail by Samson[2], was the type with two collector plates of equal lengths plus a third negative plate to maintain field uniformity. The ionizing gas used was argon, with pressures in the vicinity of 100 μHg. The ionization chamber received the light passing through the rectangular mask opening, the only correction (5-10%) being for the reduction in intensity from absorption due to argon in the monochromator. A positive potential of 18v was applied to the anode and mask, this being well into the plateau of ion current vs collector voltage. The purpose of the ion chamber was to provide a check on the absolute intensity measurements made with the thermopile at 584 Å and 735 Å (since it was already available).

The tungsten sample was mounted on a motion that enabled it to be located in the beam or completely withdrawn for thermocouple or ion chamber measurements. The sample itself was isolated electrically and connected to a grounded microammeter. The mask was placed 45v above ground for yield measurements, and served as collector for photoelectrons. A distance of about 0.5cm separated sample and mask.

It is estimated that the stray light present in any of the lines used was less than 0.5% of the peak intensity. Only prominent emission lines of the discharge gases were used.

Procedure and Results

The tungsten sample was cleaned for ten minutes in an ultrasonic cleaner in fresh Freon TF, followed by a second ten minute cleaning with a change of Freon, as requested by Harvard College Observatory.

The sample was then mounted so that the light from the monochromator covered the area marked (Fig. 2). A scan from this point toward the lower edge of the sample gave uniform yield until the beam began to fall on a discolored area near the edge. In this region the yield was lower (perhaps by 10-20%).

The sample was measured at intervals during about ten days in the vacuum system without exposure to air, with no detectable change in yield at any wavelength. The cleaning procedure was then repeated and further measurements made, again without detectable change. A lateral shift of the beam to the position shown in dashed lines in Fig. 2 again gave the same yields. The repeatability of individual measurements in these tests was about 2%.

A check for any effect due to the angle of incidence of the monochromator beam on the sample was made by rotating the sample ±15° from the previous measurement position, which was intended to give normal incidence. No change in yield was observed over this range. The values of yield (electrons per incident photon) with the standard deviation are given below. The numbers in parentheses represent the number of independent measurements made at the particular wavelength.

584 Å	735 Å	1048 Å	1216 Å
0.157±0.002(9)	0.146±0.001(8)	0.0855±0.001(6)	0.0314±0.0007(6)

An earlier investigation into the agreement in absolute intensity determinations made with ion chamber vs thermopile had shown agreement at 584 Å and 735 Å to 0.5% (with 2% standard deviation). The intensity measurements made by both methods for these yield determinations again fell within this range of agreement.

An analysis of all probable sources of consistent error in the experiment leads to an estimate of uncertainty in the yield values of about 3%.

References

1. R.G. Johnston and R.P. Madden, Appl. Opt. 4, 1574 (1965).

2. J.A.R. Samson, J. Opt. Soc. Am. 54, 6 (1964).

Figure Captions

Fig. 1 Schematic diagram of apparatus used to measure the photoelectric yield of the tungsten sample. Microammeter "A" measured either the ion current from one collector plate of the ion chamber, or the photoelectric current from the tungsten sample.

Fig. 2 Illuminated area of tungsten sample. The markings on the sample were approximately as shown on the illuminated side.

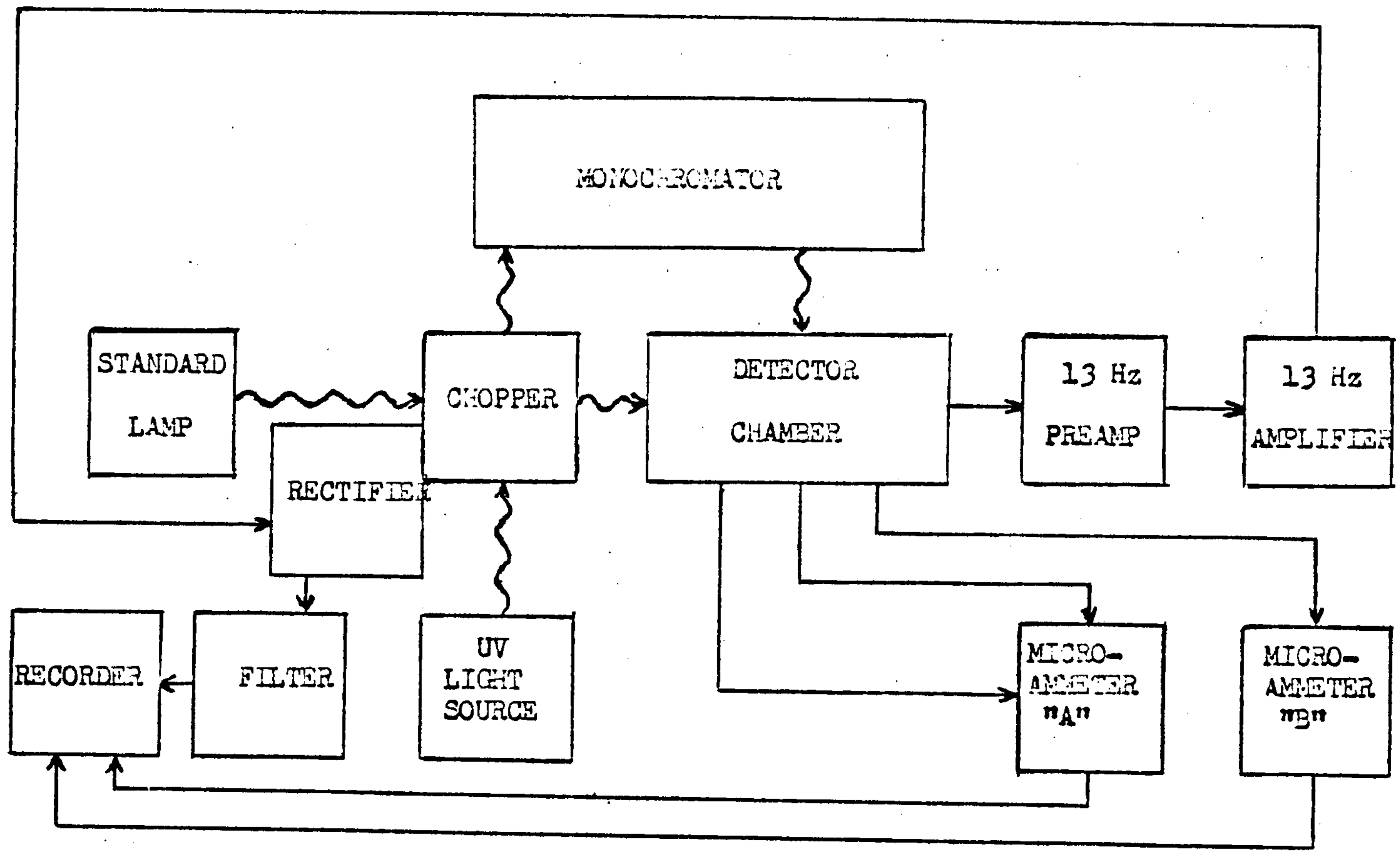
MONOCHROMATOR
STANDARD LAMP
CHOPPER
DETECTOR CHAMBER
13 Hz PREAMP
13 Hz AMPLIFIER
RECTIFIER
RECORDER
FILTER
UV LIGHT SOURCE
MICRO-AMMETER "A"
MICRO-AMMETER "B"

Figure 1

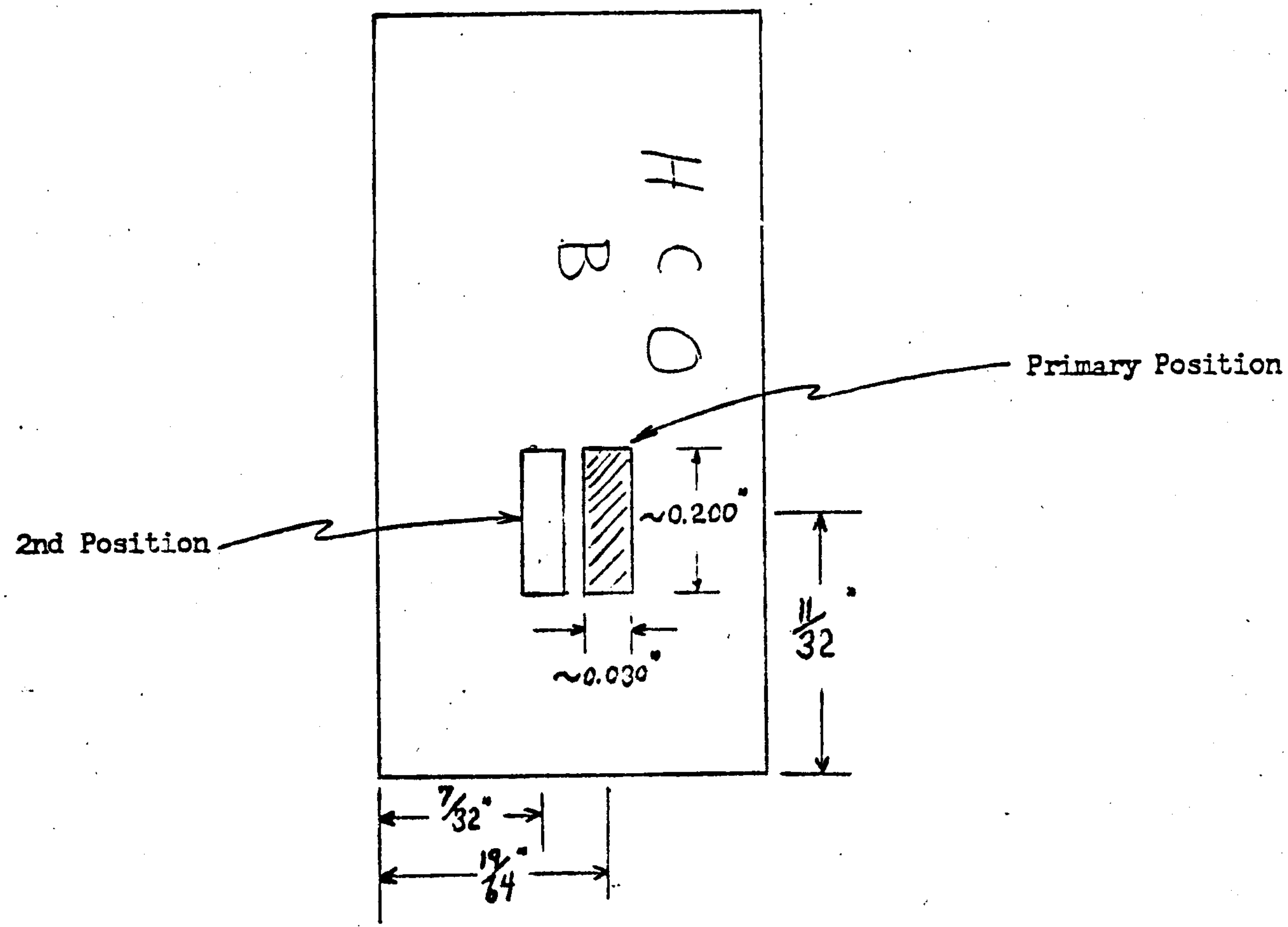

Figure 2